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"CHAPTER IV. ANALYSIS OF SOME OF THE CONTEMPORARY TYPES OF COMPOUND ANASTIGMATS. The author notes that many of the modern compound anastigmats are nearly symmetrical. To this group belong the 'universal' types of Orthometar and Express, wide-angle lenses of the Russar type, and fast anastigmats of the Planar and Kino-Plasmat types. These systems appeared in different countries and at different times, and they resulted from extended explorations and accumulations of experience.

2. "Now, as vividly expressed by him, the author gives a 'theoretical proof of the existence' of these types. In other words, he formulates the problem of designing symmetrical or nearly symmetrical anastigmats having certain nominal characteristics of speed and angular coverage. Then he explores the field of possible third-order solutions and shows that the most favorable solutions represent the forms which closely approach those used in the construction of the actually existing lenses mentioned above.

3. "It should be noted that, although the procedures used in this chapter appear to be very ingenious, they do not necessarily establish an expedient method for purely theoretical derivations of satisfactory forms. Indeed, in the course of his analysis and synthesis, the author finds it necessary to use some empirical criteria which help to confine his efforts to the most promising regions. Since these criteria are based on a pre-

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vious analysis of existing successful systems, one may say that the author actually does not reveal a new powerful tool which could be used for rapid derivation of new basic forms. Even if this conclusion is true, it does not indicate that the author was defeated in his undertaking. As I noted in the section headed 'General Review', the author never intended to demonstrate methods which would automatize lens design. His thesis is that third-order analysis and synthesis are extremely useful tools in the hands of an optical designer who possesses sufficient experience, imagination, and intuition. The material presented in Chapter IV, as well as in the subsequent chapters, illustrates this thesis to the entire satisfaction of the writer of this review.

4. "CHAPTER V. METHOD OF DISTRIBUTION OF THIRD-ORDER ABERRATIONS IN NON-SYMMETRICAL SYSTEMS CONTAINING COMPONENTS OF FINITE THICKNESS. This chapter covers third-order synthesis of the systems typified by the Sonnar, Biotar, and Uran (Volosov) lenses. The author notes that all these systems were developed prior to the appearance of the newest (silica-free) glasses, and the question arises whether or not these glasses could serve as effective parameters for improving the systems under consideration. In the presence of a multitude of other parameters, this question cannot be answered without extended systematic investigations. Such investigations are substantially simplified if the components (the 'halves') of the systems are studied separately, using the method of 'distribution' of third-order aberrations.

5. "The relationships explored in this chapter are used for deriving a formula of the Hypergon type, which differs from the original Hypergon by the asymmetrical placement of the diaphragm and by the use of thallium bromo-iodide crystal instead of glass. The formula is f/7 (which is much faster than the original Hypergon), and it covers a total field of nearly 120 degrees. The formula is completely specified and its aberrations are listed, indicating a correction which should be considered as being satisfactory for this type of construction.

6. "In connection with the derivation of this wide-angle formula, a summary is given of the Rusinov method for improving vignetting characteristics of wide-angle lenses. It is shown that, as a result of his studies of vignetting, Rusinov succeeded in securing with the Russar-25 a much better illumination distribution than was previously obtainable with wide-angle lenses. With the Russar, relative illuminance is nearly directly proportional to $\cos^3 A$, while with lenses of the Hypergon and Topogon types the relative illuminance at the marginal angles drops faster than $\cos^4 A$. I might note here that an improved illumination distribution was also obtained for the Aviogon lens, recently introduced by the Wild Company (Switzerland). There are indications that the deductions of the Rusinov theory were directly or indirectly utilized in securing the favorable vignetting characteristics of the Aviogon.

7. "This chapter includes also the relationships which express the first-order chromatic aberrations of a whole system in terms of the chromatic contributions of its 'halves'.

8. "CHAPTER VI. EXPRESSION OF ABERRATIONS OF A COMPOUND PHOTOGRAPHIC SYSTEM THROUGH THE ABERRATIONS OF ITS COMPONENTS. The author divides the process of designing a photographic system into three stages:

1) Third-order explorations;
2) Preliminary checking and evaluation of the most promising variants;
3) Final correction of the variant which appears to be able to yield an optimum solution.

9. "There is nothing original in this division as it follows naturally from the

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substance of the problem. The originality of the author is in his idea that, at the second stage of a design, the work may be considerably expedited by determinations of aberrations of the 'halves' and then the use of relatively simple combination formulas for computing the aberrations of the whole system. Of course, the results are not exact, but the approximation is sufficiently good for purpose of the explorations at the second stage.

10. "Several examples are given which illustrate a satisfactory agreement between the approximate formulas and the exact trigonometric ray-tracing.

11. "CHAPTER VII. DIFFERENTIAL METHOD FOR DETERMINATION OF CHANGES OF COORDINATES OF RAYS IN THE IMAGE SPACE WHEN CHANGES OCCUR IN THE PARAMETERS OF AN OPTICAL SYSTEM. Approximate differential formulas are given for direct transformation of the changes in the front half of a system to changes of aberrations of the whole system. The method does not seem to be substantially different from other differential methods of transfer of parameter changes. Volosov claims that his method offers a substantial amount of time-saving in computations of change tables. Whether or not this claim is justified cannot be determined without a comparative study of methods.

12. "CHAPTER VIII. SOME NOTES ON SETTING-UP AND COMPUTING OF COMPOUND PHOTOGRAPHIC SYSTEMS, PARTICULARLY OF THOSE OF HIGH SPEED. The author states that special attention should be given to the problems involved in the design of high-speed photographic lenses, a demand for which exists in many fields of modern technology. An incomplete listing of these fields is: night photography, motion-picture color photography, X-ray photography, some applications in spectrography, 'seeing' with ultra-violet and infra-red rays, and television.

13. "High-speed lenses are defined as those which are faster than f/3. Their prototypes are: the Petzval lens, the Taylor Triplet, and the Rudolph Planar. Some representative lenses of these types are analyzed and their performance is commented upon.

14. "Volosov states that very interesting results were obtained in the course of recent Russian investigations of these systems with a view to the possibility of their further improvement. The results of these investigations are not given, but they served as a basis for the following evaluation of foreign lenses: 'The German systems are on a relatively low level of quality from the point of view of correction of aberrations. The optical characteristics of the American anastigmats do not justify their constructional complexity.'

15. "This chapter contains also a general outline of the procedure to be followed in the design of a compound objective, and some empirical rules are given with regard to the selection of glasses, the maximum relative powers of the components, the length of the system, and the desirable values of the Seidel coefficients. The necessity of a satisfactory third-order correction is again emphasized.

16. "Standard presentation of computed aberrations is illustrated. The presentation is essentially the same as in this country and elsewhere, but more emphasis is given to determination of the plane of best imagery and to summarizing the aberrations in this particular plane. A summary of aberrations usually consists of tabulations and graphs showing the image spreads in the meridional and the sagittal sections, But occasionally numerous skew rays are computed in order to determine the complete geometrical image shape, and also to construct a 'spot diagram' of the image (this is the form of representation which has been recently introduced by the National Bureau of Standards in this country).

"PART II. METHODS OF DESIGNING PHOTOGRAPHIC SYSTEMS WITH VARIABLE OPTICAL CHARACTERISTICS ('ZOOM' LENSES).

17. "Introduction. Photographic systems of variable optical characteristics (known

in this country as 'zoom' lenses) may prove useful in many applications. According to Volosov, the work on such systems started in the thirties of this century, but a 'serious analysis of the problem of their design is not available in the foreign literature', and the progress in Russia was interrupted by the war.

18. "The author gives an interesting historical summary of the problem, and traces the formulation of some principles of variable systems to Kepler's 'Dioptrics' (1611). The first practical attempts to develop a variable telescopic system were made by H. Landolt in 1876, and the efforts were continued by other authors. During the First World War, the German fleet successfully used variable ('pancratic') telescopic systems for fire control in the Battle of Jutland.

19. "The idea of developing variable photographic lenses originated in the middle of the last century, but no practical results were achieved until the nineties, when telephoto lenses of variable magnification were introduced. All these lenses were reasonably well corrected for only one medial magnification setting; but even at that setting the distortion and oblique color were very substantial. Furthermore, these lenses were relatively slow and covered small angular fields.

20. "As was stated before, the work on modern 'zoom' systems of high speeds and covering substantial angles was started only in the thirties. As evaluated by Volosov at the time of his writing the book (1948), none of these lenses was very satisfactory, either because of the complexity of construction or because of inferior correction of aberrations. He implies that the Russian variable-focus lens, 'Idar', developed by him before the war (no sample was made due to interference of the war), appears to represent a better solution, considering the unusual simplicity of construction and a satisfactory correction of the aberrations. This lens is one of the many variants obtained in the course of extensive explorations, the results of which are summarized in the following chapters.

21. "CHAPTER IX. CONCERNING THE DESIGN OF PHOTOGRAPHIC SYSTEMS WITH VARIABLE OPTICAL CHARACTERISTICS. The problem, as formulated by Volosov, is one of designing a variable focal-length lens of a relatively simple optical and mechanical construction. For the purpose of preliminary design, the system is assumed to consist of only three thin components.

22. "The paraxial optics of such a system are thoroughly explored in this chapter, and sixty-three paraxial solutions are listed in a table. These solutions are further analyzed with the aim of securing a satisfactory third-order correction for two equivalent focal lengths which are near the maximum and minimum values of the specified range. This analysis results in sixty-six third-order solutions, which are not strictly distortion-free for any focal length within the range. Finally, twelve solutions are obtained with which the system is distortion-free at the setting for a medial value of focal length.

23. "This chapter contains a great amount of basic material which can be profitably studied and exploited by any lens designer interested in the problem of 'zoom' lenses.

24. "The author points out that one of the types derived in this chapter represents the same basic scheme which was used in the design of the German 'Vario-Glaukar'; another type was utilized in the construction of the English 'Cooke Varo-Lens'. A third type served as a basis for the Russian 'zoom' lens, 'Idar', which is discussed in the following chapter.

25. "CHAPTER X. AN ILLUSTRATION OF THE METHOD BY THE EXAMPLE OF DESIGNING OF THE OBJECTIVE 'IDAR'. A most promising basic construction was selected from the

"PART III. ABOUT THE USE OF NEW TYPES OF OPTICAL GLASSES, ASPHERICAL AND REFLECTING SURFACES, IN DESIGNING OF OPTICAL, IN PARTICULAR PHOTOGRAPHIC SYSTEMS.

30. "CHAPTER XII. OPTICAL CONSTANTS OF GLASSES AS PARAMETERS IN DESIGNING OF PHOTOGRAPHIC SYSTEMS. The author emphasizes the fact that only in the simplest optical systems (doublets and triplets) are optical constants of glasses (their indices and dispersions) design parameters whose significance can be uniquely established. In more complex systems, optical constants of glasses may be either effective or only 'apparent' parameters. It is difficult to determine analytically what the actual situation is in each particular case of lens design.

31. "However, occasionally an analysis proves to be fruitful. Thus, the author succeeded in establishing the effectiveness of glasses as parameters in the designing of orthoscopic telephoto objectives. This matter is covered in the following chapter.

32. "The effectiveness of glass constants in the designing of simple systems is illustrated by two examples. One shows that the Petzval sum can be considerably improved by using one of the new (rare-earth) glasses in the crown element of a doublet. The other shows that these new glasses permit a considerable improvement of the Hypergon design, and an increase of its speed, from the original f/30 to f/10. A sample formula of the improved design is given. The formula has two elements using 1.7279-54.6 glass. As is true with the original Hypergon, the new form is not corrected chromatically, but it can be achromatized by splitting each of the elements into two in order to introduce 1.7280-28.3 flint; this splitting will leave the monochromatic correction unchanged because of the practical identity of the indices.

33. "The Eastman Kodak 7" f/2.5 Aero-Ektar (seven elements) is used as a highly representative illustration of a case in which a lens designer was misled into thinking that rare-earth glasses were needed to effect a certain state of correction of the formula. Volosov dedicates ten pages to an analysis of this Aero-Ektar, and he shows that a practically identical correction of all the aberrations could be obtained with ordinary glasses. He concludes, with some sarcasm, that the rare-earth glasses were only apparent design parameters in this formula and that their use was superfluous. But he does not want to imply that not much can be expected from new glasses in general, and he emphasizes the necessity of further systematic studies with the aim of establishing the areas of usefulness for these glasses.

34. "CHAPTER XIII. BASIC PARAMETERS OF ORTHOSCOPIC TELE-OBJECTIVES WITH CORRECTED PETZVAL CURVATURE, AS FUNCTIONS OF CONSTANTS OF OPTICAL GLASSES. The reason for placing this chapter in this particular part (Part III) of the book is that it was shown by investigation that construction parameters of these types of lenses are explicit functions of glass indices.

35. "Noting that literature on the methods of designing tele-objectives is scant, the author derives first- and third-order relationships which are characteristic of telephoto construction. They show that the basic construction parameters are dependent on indices.

36. "Considering the importance of glass constants in the process of telephoto design, the author does not omit in this case an exploration of the achromatization problem. The formulas here derived show that the secondary color cannot be reduced with any combination of the available glasses unless the speed requirements are lowered to about f/15.

37. "Special attention is given to the problem of relatively fast constructions

list in the preceding chapter, and from this a third-order synthesis of a formula was made for a range of focal lengths from 50 mm to 175 mm. In the final correction of the formula, a number of satisfactory variants were studied. The author gives complete optical specifications for one of the variants (not necessarily the finally selected formula), and shows a very satisfactory correction of the trigonometrically computed aberrations for the entire range of the focal lengths.

26. "The formula of this variant consists of three components, each of which is a cemented doublet. One component is a negative double-concave doublet. It is located in the front of the system, which fact makes the whole scheme rather unusual. The formula covers a range of focal lengths from 59.9 mm (a total angle of coverage of about thirty degrees) to 179.8 mm (a total angle of coverage of nearly ten degrees). The speed is f/3.5 up to about 140 mm focal length; for the longer focal lengths it is f/5.6. The mechanical linkage of the components (Volosov uses the term 'kinematics of the system') is simple.

27. "Generally speaking, the material summarized in this chapter indicates that the Volosov team has succeeded in deriving a very satisfactory solution of the 'zoom' lens problem. Whether or not this solution should result in better 'zoom' lenses than those now manufactured in this country and Europe cannot be foretold without a more thorough study of all the data and an actual testing of representative samples.

28. "CHAPTER XI. ABOUT DESIGNING OF TELE-OBJECTIVES WITH VARIABLE FOCAL LENGTH. Among the basic solutions listed in the preceding chapter, there are also two groups which contain lenses with telephoto characteristics. These groups are further studied in this chapter. Sixty-nine paraxial solutions are obtained, eleven of which are used for a synthesis of formulas with a satisfactory correction of third-order aberrations.

29. "No formula is given in a final form. The main purpose of the study was apparently to determine the basic relationships and limitations inherent in the task of designing a telephoto with variable focal length. The resulting conclusions are listed as follows:

1) The systems explored in this chapter do not permit a variation of focal lengths by greater than a factor of 1.5.

2) Their telephoto ratios are confined within a range of from 1.10 to 1.25.

3) There are no difficulties in obtaining a satisfactory Petzval sum, but distortion correction presents a serious problem.

4) For the variation and telephoto ranges indicated under items (1) and (2), the Seidel distortion is rather high. It may be acceptable for reconnaissance photography, but not for precision photogrammetric purposes.

5) The speeds will have to be relatively low (f/9 to f/7). Even for these speeds, it would be necessary to use multi-element components in designing the formulas.

6) Distortion characteristics of these systems can be improved only by reducing the focal-length variation factor to about 1.15. Even then, the condition of orthoscopy can be strictly satisfied for just one focal length within the range.

(f/5 to f/7) and high telephoto ratios. The author concludes that telephoto ratios higher than 1.4 are not attainable in the range of these speeds if a corrected Petzval is also specified.

38. "This chapter contains an incidental listing of standard Russian glasses. The listing is complete, and it reveals the very interesting fact that already in 1948 the Russian catalog contained as many as forty-seven glasses, while the current Bausch and Lomb catalog contains only thirty-seven glasses, although the latest Hayward catalog lists fifty-three.

39. "The theoretical deductions of this chapter are used to determine the basic parameters of two two-component telephotos. The author shows that one of these telephotos is of nearly the same construction as the German Telikon, and the other does not differ much from the British Telephoto-Anastigmat of Taylor-Hobson. The Tele-Cooke-Anastigmat (f/3.5, covering a total angle of thirty degrees) is also mentioned (but not analyzed) as a system which falls within the range of the solutions derived in this chapter.

40. "CHAPTER XIV. INTRODUCTION OF ASPHERICAL SURFACES INTO OPTICAL, PARTICULARLY PHOTOGRAPHIC, SYSTEMS, A DIFFERENTIAL METHOD. The author notes that an expedient method of introduction of aspherical surfaces should necessarily give answers to the following three questions, already raised in the preliminary stage of a design:

1) Aspherization of what surface in a given system would particularly favorably affect the image-forming pencils of rays?

2) How can the form of an aspherical surface be determined without time-consuming computations of the coordinates of the rays refracted at this surface?

3) How can one evaluate, at least approximately, the effect of an aspherized surface on all the aberrations?

41. "The method described in this chapter gives satisfactory answers to the three questions listed above. It is based on differentiation of the coordinates of the rays (in the space after the aspherized surface) with respect to the coefficients of the series expansion representing the aspherized surface. The differential changes thus determined are then transferred in the final image space.

42. "Depending on the specific requirements of a design problem, four transfer procedures are formulated as listed below:

1) Transfer for a case of an aspherical surface being the last one in the system.

2) Transfer based on the assumption of very narrow pencils and of paraxial relationships.

3) A simplified transfer suitable in a case of very small deformations.

4) Transfer based on utilization of a change table computed with spherical surfaces.

43. "Application of these four procedures is illustrated in the four subsequent sections.

44. "CHAPTER XV. ILLUSTRATION OF APPLICATION OF THE DIFFERENTIAL METHOD OF ASPHERIZING. The method is applied to two examples. One is a single thick

lens with one aspherical surface; the aspherizing is achieved by relatively simple computations. The result is an f/3 lens with well corrected monochromatic aberrations for a focal length of 100 mm or even somewhat longer, and covering a total field of thirty degrees. Since the lens is rather thick, it can be easily split into a doublet and achromatized. The formula of an achromatized doublet is also given in the text.

45. "The second example illustrates the improvement which was obtained by aspherizing the first surface in a system of the Express type. The improvement is substantial, not only on the axis but also for an intermediate field angle of 18.5 degrees.

46. "CHAPTER XVI. SYSTEMS COMBINING MIRRORS AND LENSES (CATODIOPTRIC SYSTEMS). This chapter is dedicated to a study of a theory of refractive components which may be used for compensating the aberrations of spherical mirrors. The theory developed here covers only components with spherical surfaces, as such systems offer definite manufacturing advantages in comparison with the systems requiring aspherical surfaces.

47. "The characteristics of the following two compensators are evaluated in great detail. The first is the single thick meniscus compensator developed by D D Maksutov, and the second is the afocal two-element compensator developed by Volosov and his co-workers.

48. "The Volosov compensator is particularly interesting in that it offers a powerful means for correcting catodioptric systems as fast as f/1.2 with a total angular coverage of fifteen degrees. Furthermore, its two elements have realtively flat surfaces, and they do not, therefore, cause the manufacturing and assembly difficulties which are usually associated with the strongly curved Maksutov meniscuses.

49. "A third-order theory of these two compensators is developed and applied to examples of practical design.

"APPENDIX II. References

1. "The book contains thirty-one references to Russian literature and seven references to foreign literature. Three of these references represent the basic material, the knowledge of which is necessary for proper use of the Volosov book. As listed in this memorandum, these references are:

   1) A I Tudorovskij, 'Theory of Optical Instruments', Academy of Sciences, 1937.

   2) G G Sljusarev, 'Methods of Design of Optical Systems', O N T I, 1937.

   3) A I Tudorovskij, 'Computation of Third-Order Aberrations with Lange's Formulas', Journal of Technical Physics 13:230, 1943.

"APPENDIX III. Index of Lenses Mentioned in the Book

(Rus) after the lens name indicated that the formula is Russian.

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